Pedestrian Assistance System Utilizing iOS LiDAR

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Abstract. Along with the increase in the spread of smartphones, the use of smartphones while walking has increased, and the resulting accidents has also increased. There are signs and exclusive roads implemented to prevent accidents caused by smartphone use while walking, but these measures are limited to specific areas. So, this paper creates a system to assist pedestrians without limitations to specific locations, utilizing the LiDAR sensor of the iOS Pro model. LiDAR provides accurate height information for objects in the frontal direction compared to a camera. However, the LiDAR detection range for the front varies depending on the angle of the smartphone, and individuals may use the smartphone at different angles. To address this, the angle of the smartphone is measured using an acceleration sensor. The angle error caused by the change in acceleration during walking is corrected using the first-order low-pass filter, and the angle is 4.13% more accurate than before the correction. In addition, three LiDAR ranges are set according to the angle, and the height change of the set range values is detected using the first-order low-pass filter. Finally, a pedestrian assistance system is created to alert pedestrians to danger if the height is more than 10cm before.

Keywords: Pedestrian Assistance System · Mobile App · LiDAR

1 Introduction

1.1 Pedestrian Smartphone Usage Accidents

As the spread of smartphones increases, accidents caused by smartphones are increasing. Among the many accidents caused by smartphones, this paper focuses on accidents caused by using smartphones while walking. As mentioned in [1,2,8], using a smartphone while walking is a problem. The reason for the problem is that the pedestrian's field of view narrows as shown in Fig. 1 when walking using a smartphone. When the smartphone is not used, the field of view is θ, and when the smartphone is used, the user's field of view is $\theta^{'}$. Narrow vision increases the risk of a collision or fall accident [11]. Many countries have installed signs and exclusive roads to reduce smartphone usage accidents while walking. But, these are limited to certain locations. It is advisable not to use smartphones while walking. However, as can be seen from the results of Fig. 2 that surveyed 37 people online, they think using a smartphone while walking is dangerous, but most of them use it. That is why this paper wanted to create an auxiliary system

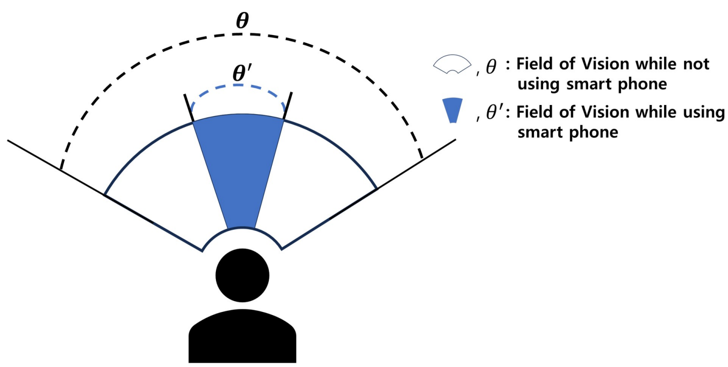

Fig. 1: Changes in Field of View depending on smartphone use during walking

that is not limited to places to reduce the risk of walking. Considered sensors to assist the limited field of view for pedestrians on mobile devices are the camera or the LiDAR in the iOS Pro model. Among them, an auxiliary system is created using LiDAR, which has many advantages in terms of accuracy.

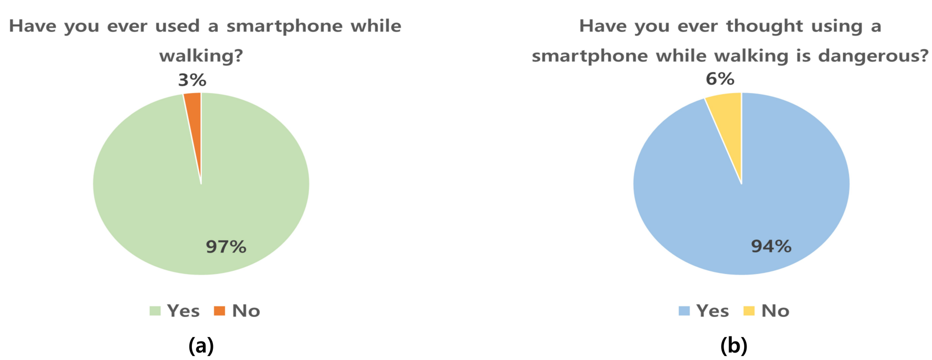

Fig. 2: (a) is result of the number of smartphone users while walking and (b) is result of someone who uses a smartphone while walking but thinks it's dangerous

2 Background

2.1 LiDAR

LiDAR stands for Light Detection And Ranging and uses light to measure distance. LiDAR, due to its ability to accurately perceive the surrounding environment, is employed in applications such as 3D modeling, robotics, and autonomous vehicles. iPhone Pro model is equipped with LiDAR, providing more accurate distance measurements compared to distance measurement methods using the camera. Furthermore, it is less affected by the surrounding environment and can be used seamlessly both day and night. The distance measurement method employed by the iPhone LiDAR is the dToF (direct ToF).

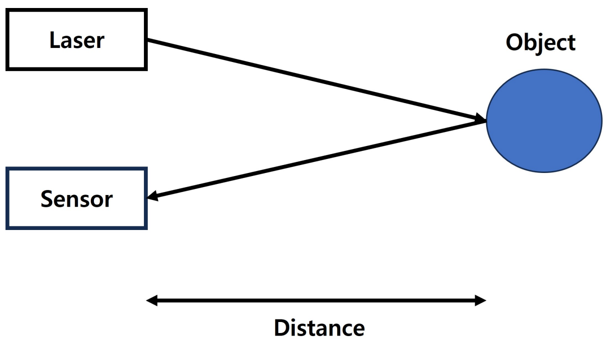

Fig. 3: The measurement technique of dToF (direct Time-of-Flight) uses the time it takes for the emitted light from a Laser to be detected by the Sensor, enabling the calculation of distance.

As shown in Fig. 3, dToF measures the distance through the time when the light comes out of the laser and returns to the sensor after hitting the object. The equation for obtaining the distance is (1). 'd' is the distance, 't' is the time when the light from the laser reaches the sensor, and 'c' is the speed of light.

$$d = \frac{t}{2} * c \tag{1}$$

LiDAR is suitable for use in auxiliary systems because it can measure distances in real time. There are various methods of using LiDAR on the iPhone, but this paper uses Unity ARFoundation.

2.2 Unity ARFoundation

Unity is a program that produces various 3D and 2D contents, and various functions can be used. Among them, ARFoundation is a framework that helps create AR applications [6]. ARFoundation offers various features such as ambient light estimation, face recognition, and plane detection. Additionally, devices equipped with LiDAR allow the use of LiDAR capabilities. And with the raycast function, LiDAR-specific points can be used. In Unity, the raycast function is capable of identifying collisions with objects by projecting rays in specific directions. When integrated with ARFoundation, this function can measure distances by detecting collisions with LiDAR points at predefined locations on smartphone screens.

2.3 Accelerometer

The accelerometer can be used to determine the angle at which pedestrians are looking at their phones and to ascertain whether they are walking. The accelerometer can be utilized for collision detection, position estimation, speed estimation, and more. The accelerometer in smartphone, as shown in Fig. 4, detects motion along the x, y, z axes in three dimensions. The accelerometer is widely used in health-related applications, enabling features such as step counting, angle measurement, and position estimation for pedestrians.

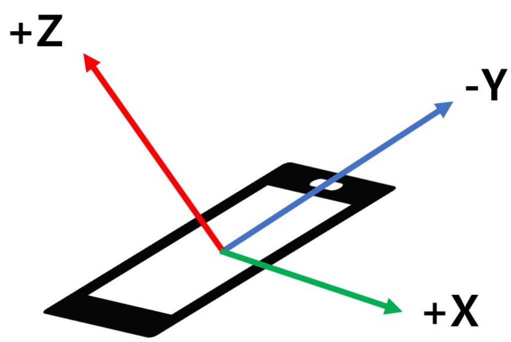

Fig. 4: The accelerometer of the smartphone provides data along three axes: X, Y, Z

3 Proposed Method

The advantage is taken from the fact that the LiDAR on the smartphone has a broader field of view than the actual visual range of a pedestrian using the device. To identify obstacles in the pedestrian's path, LiDAR is employed to measure the height of objects in the forward direction. The working mechanism of the proposed application is outlined in Algorithm 1.

Algorithm 1 **How the application works**

```
// Check for the execution of the application
appStatus ← CheckApplicationExecution()
while appStatus do
    // Calculate smartphone angle
    θ ← CalculateSmartphoneAngle()
    // Determine Lidar range based on angle
    if 0 ≤ θ ≤ 25 then
        lr ← GetLidarRange(0, 25)
    end
    else if 25 < θ ≤ 45 then
        lr ← GetLidarRange(25, 45)
    end
    else
        lr ← GetLidarRange(45, 60)
    end
    // Apply Lowpass filter to the y-value of the LiDAR point
    lp ← LowpassFilter(ObtainLidarPoints.y(lr))
    // Check for danger
    if |lr − lp| > 10 then
        Warn(Warning Sound)
    end
end
```

3.1 Pedestrian smartphone angle measurement

Pedestrian holding smartphone while walking exhibit varying angles. The detectable range of LiDAR in the forward direction varies based on the smartphone angle. As the smartphone approaches a horizontal position, both the LiDAR detection range of the surroundings and the pedestrian's field of view narrow. Conversely, when the angle is closer to vertical, both the detection range of LiDAR and the pedestrian's field of view expand. To apply this difference, the accelerometer is utilized to estimate the smartphone angle. Based on this angle, the LiDAR detection area is specified. The angle estimation uses the z-axis and y-axis values of the accelerometer. The approach to calculating the smartphone angle involves determining the angle 'a' as illustrated in Fig. 5. The formula for calculating angle 'a' is provided in (2). Since these values are in radians, (3) is applied to obtain the degree values.

$$tan(a) = \frac{y}{z} \Rightarrow a = tan^{-1}(\frac{y}{z}) \quad (2)$$

$$degree = \frac{180}{\pi} * radian \quad (3)$$

The angle can be obtained using an accelerometer, but there is a problem. As shown in Fig. 6.(A), there is no problem when stopping, but problems arise when the accelerometer values fluctuate during walking or running. This phenomenon

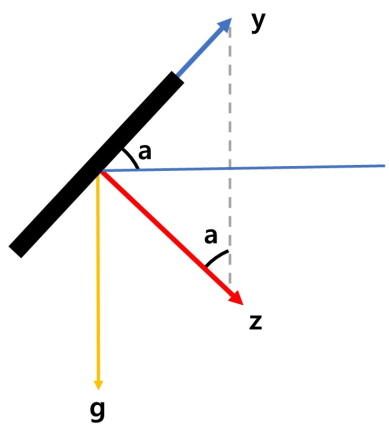

Fig. 5: This illustration depicts the accelerometer axes and angles on a smartphone. The black rectangle represents the smartphone. The angle can be obtained using the z,y values of the accelerometer

occurs because the body moves up and down while walking. The accelerometer values exhibit vibrations, but the angle of the smartphone does not change. To address this, a first-order low-pass filter is employed for correction. The formula for the first-order low-pass filter is given by Equation (4).

$$\hat{x}_n = \alpha \hat{x}_{n-1} + (1 - \alpha) x_n \tag{4}$$

In Equation (4), $\hat{x}_n$ represents the current estimated angle, $\hat{x}_{n-1}$ is the previous estimated angle, x_n denotes the current measured angle, and α is an arbitrary constant. In this paper, α is experimentally set to 0.9 to give more influence to the previous value. As a result, satisfactorily corrected angles are obtained, as shown in Fig. 6.(B).

3.2 Specify LiDAR Detection Range according to Angle

To experimentally define the LiDAR detection range based on angles. The angles are categorized into three cases, with reference to [7]: $0° \sim 25°$, $25° \sim 45°$, and $45° \sim 60°$. Fig. 7 represents the LiDAR detection range for three different cases. The upper graph depicts the detection range on the smartphone screen, and the figure at the lower shows the actual detection range in actual execution. Fig. 7.(A) represents the case when the smartphone angle is $0° \sim 25°$. Considering the narrow LiDAR detection range in the forward direction, many points are strategically placed at the top of the screen. Fig. 7.(B),(C) are $0° \sim 25°$ and $45° \sim 60°$. It is experimentally set up to identify obstacles up to 1 to 2.5m in front.

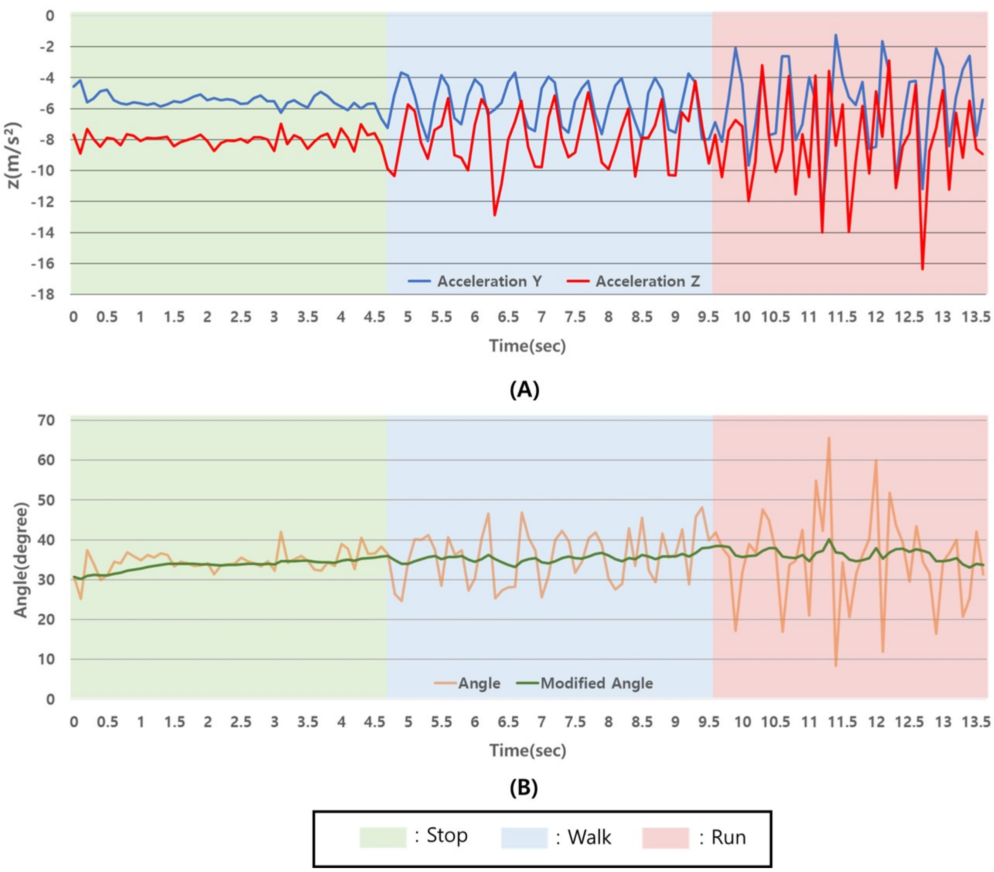

Fig. 6: This graph utilizes accelerometer values measured at a frequency of 10Hz from an iPad Pro. The sequence includes stopping, walking, and running. (A) represents the values of the Y-axis and Z-axis obtained using the accelerometer sensor. When stopped, there is minimal change in values, but when walking or running, observable vibrations in the values can be noticed. (B) is a graph showing the Angle value obtained using the formula (2),(3) for the measured y,z value and the Modified Angle value obtained using the formula (4). The oscillating values are effectively corrected using the Equation (2).

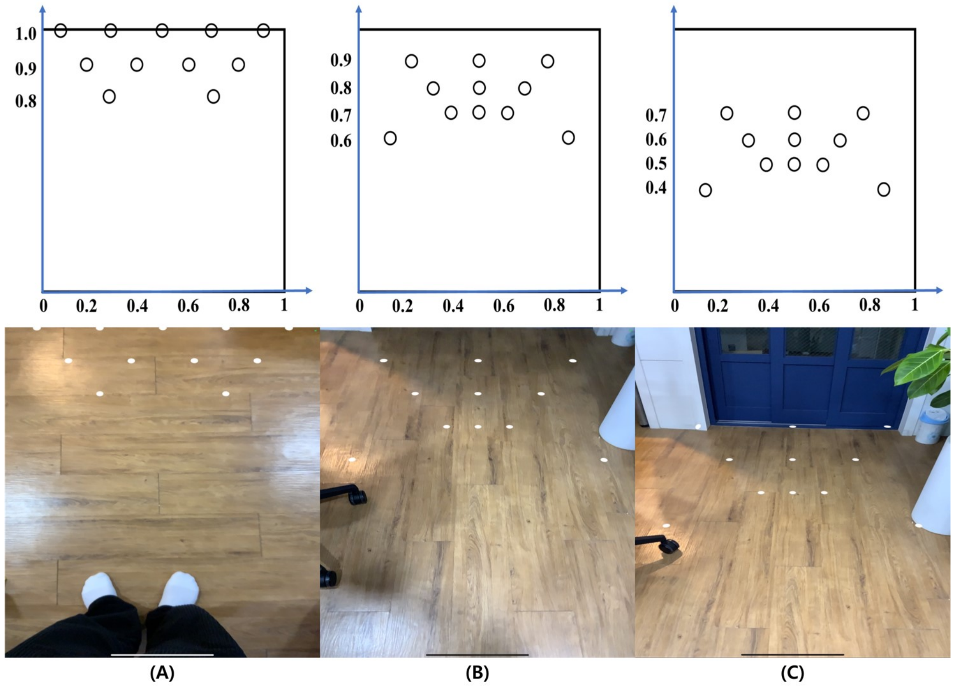

Fig. 7: The upper graph represents the normalized coordinates (ranging from 0 to 1) of a smartphone screen in both horizontal and vertical dimensions. The white points on the graph denote the detection positions of LiDAR. The lower image illustrates the application of these white points from the graph onto the actual screen.

3.3 Danger Detection Method

Trees, power poles, people, etc., which can be dangerous to pedestrians, have a height higher than the ground, and stairs, handrails, cliffs have a low height. Therefore, risk factors can be classified through height value measurement using LiDAR. Information obtained from LiDAR in Unity can be represented in 3-dimensional coordinates (x, y, z). In Unity, the y-value represents the height. So, the height value of the measurement range can be known by using the y-value. The methods of detecting danger are as follows:

1. Obtain the y-values of the used LiDAR points
2. Calculate the average using the formula (4)
3. Notify of danger when the measured value is more than 10cm or less than 10cm from the average value, using 10cm as the threshold.

The reason for using 10cm as a threshold is because in [3,9,10], a height of 10cm is defined as an obstacle. Visualizing when the actual application is executed the same as the output of Figure 8. Normally, all the points are white, but when the danger is detected, it turned red as shown in the red circle of the Output of Figure 8. Since LiDAR is used, it can be seen that obstacles are well detected even in dark places as shown in the third picture from the left.

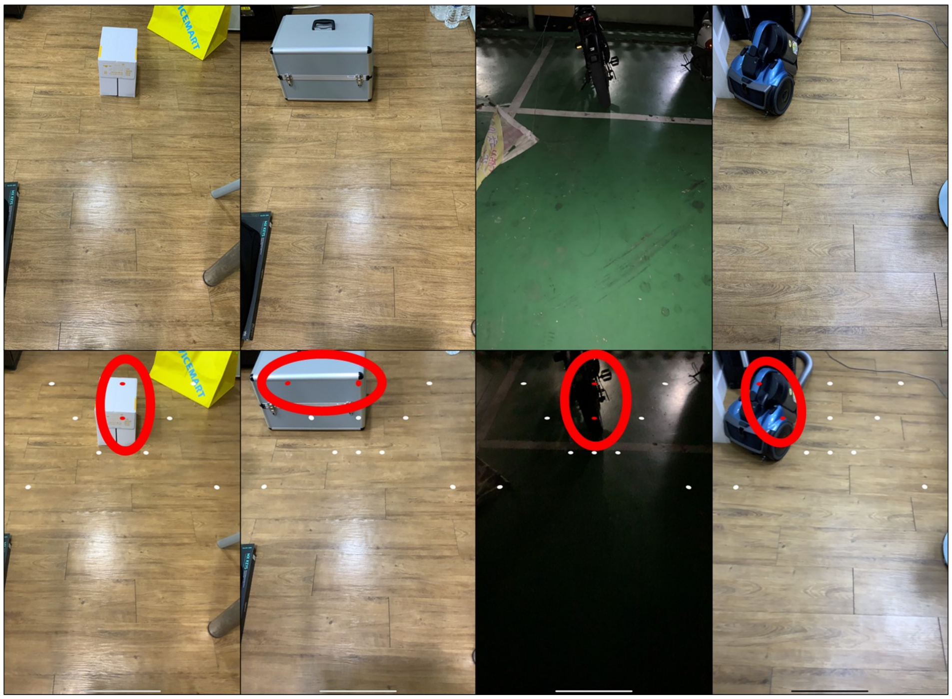

Fig. 8: The upper images illustrate situations with obstacles in the front. The bottom images visualize the execution of the pedestrian assistance system in the upper environment. It can be observed that when the assistance system is activated, obstacles in the front are detected, and the points change to red.

4 Experiment

The experiment follows the conditions below

- **Device:** iPad Pro 11-inch (2nd generation)
- **Device Height:** 110cm
- **Device Angle:** Case1(0~5°), Case2(30~40°), Case3(45~50°)
- **Number of experiments:** 90 times
- **Experimental Environment:** Box in the front, Descending stairs, Ascending stairs

The experimental method measured the distance of the pedestrian's foot when the warning sounded while walking. The graph of the measurement results is Fig. 9. The average measurement distance for each situation is shown in Table 1.

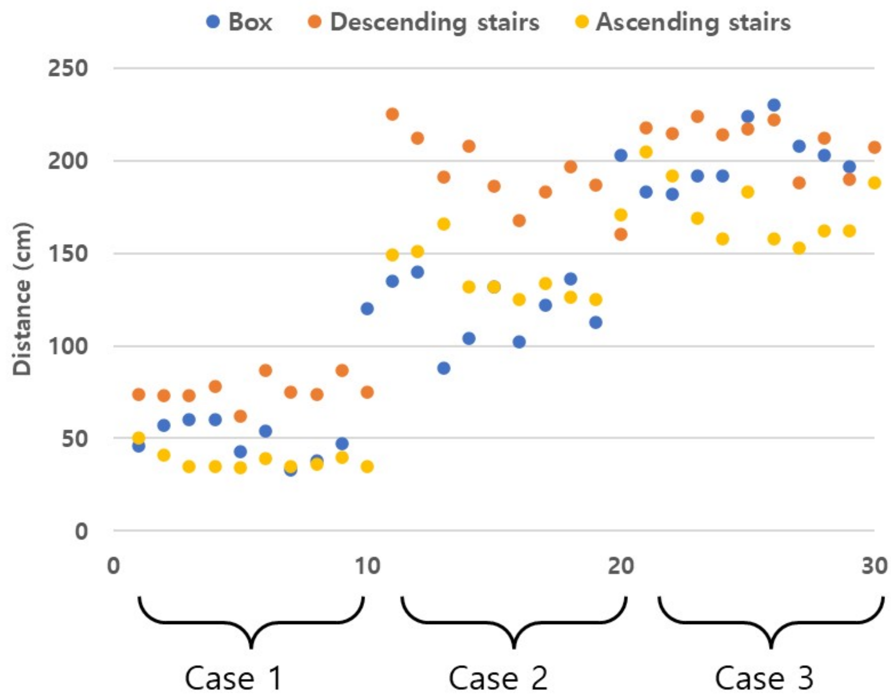

Fig. 9: This graph displays the distances measured between obstacles and pedestrians in various scenarios. The cases are categorized based on the device angles, revealing that as the angle increases, the measured distances also become longer.

4.1 Ablation Study

Accuracy calculation based on the α value of the Low-pass filter. To correct the error in the angle measurement of the pedestrian holding the smartphone (4), the constant α is changed and the error is measured. The Error measurement method obtains the absolute value of the difference between x_{real} (real angle) and $x_{measure}$ (measurement angle). It is divided by multiplying the actual angle by n (number of measurements). Finally, it proceeds in the form of multiplying by 100 to obtain %. The Equation is (**??**).

Table 1: Average of measurement distances by situation

	Box	**Descending stairs**	**Ascending stairs**
Case1	48cm	75.8cm	38cm
Case2	119.2cm	191.7cm	141.1cm
Case3	201.4cm	210.7cm	173cm

$$\frac{|x_{real} - x_{measure}|}{x_{real} * n} * 100 \qquad (5)$$

The graph illustrating the variation in angle concerning the change in α is shown in Fig. 10. and the corresponding error values are presented in Table 2.

Table 2: Variation in Error Values with Respect to α Values

	Angle	**α=0.1**	**α=0.3**	**α=0.5**	**α=0.7**	**α=0.9**
Error	19.01%	18.11%	16.75%	15.88%	15.35%	14.88%

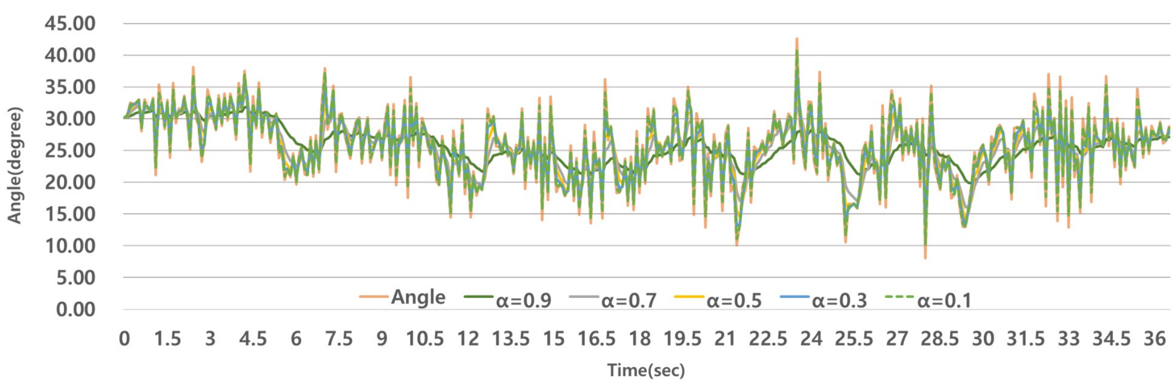

Fig. 10: This graph illustrates the variation in angles with different α values when utilizing a low-pass filter.

Using MobileNetV3 To enhance the performance of the pedestrian assistance system, experimenting involved the combined use of data acquired through LiDAR and a deep learning classification model. The employed classification model is MobileNetV3 [5]. This model is good for use as a deep learning network in mobile applications due to its low parameters and high accuracy. ImageNet dataset [4] is used as the training dataset. To process data captured by the camera and resizs the upper 1/3 portion of the images, representing the farthest distance recognized by the camera, to 224x224 pixels. These resized images are used as inputs for the classification model. If elements classified as vehicles are detected in the user's walking path, a warning is issued to alert about the potential risk. However, when it is applied, it consumes a lot of batteries and the CPU calculation ratio is high, making it less real-time. Considering these issues as significant drawbacks for applying it to a mobile app, the application is finalized by removing the previously implemented classification.

5 Conclusion

Smartphone use while walking is dangerous and this is a social problem. So, this paper proposes a solution to this issue that involves using LiDAR technology in the iOS Pro model to provide distance information with higher accuracy than the camera. The LiDAR range to the front varies based on the angle at which a pedestrian holds their smartphone. To address this, utilizing the smartphone accelerometer to determine the angle and designating specific LiDAR detection ranges corresponding to these angles. In addition, a method of correcting the accelerometer value is also suggested because the accelerometer value is shaken according to the pedestrian's way of stopping, walking, and running. The angle correction resulted in an angle value that is 4.88% more accurate than before. Changes in the height of the front objects are detected, warnings are given if the change occurred more than a certain value, and the performance is confirmed through experiments. As a result, a system has been created that can assist pedestrians according to the angle of the smartphone.

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